DISCUSSION

4.1. Overview of Findings

The issue of excessive flightcrew fatigue, as a result of trip exposure, has been a primary concern of the aviation community for a long time, but there has been little tangible evidence with which to confirm or deny the extent or operational significance of fatigue associated with duty-cycle exposure. We have discussed how laboratory studies have been of little use to those interested in aviation safety because of the difficulty of generalizing laboratory performance measures to the task of operating a complex aircraft. Thus, the operational significance issue was a pivotal part of this investigation.

This study examined the performance of 20 volunteer twin-jet transport crews in a full-mission simulator scenario that included many aspects of an actual line operation. The scenario involved both routine flight operations and an unexpected hydraulic failure complicated by weather problems that resulted in a high level of crew workload. Approximately half of the crews flew the simulation within two to three hr after completing a three-day, high-density, short-haul duty cycle. The other half flew the scenario after an average of three days off duty. The high-density duty cycles that were the focus of this investigation averaged eight hr of on-duty time per day and five takeoffs and landings, with at least one day (usually the last) averaging close to thirteen hr of duty and eight takeoffs and landings. These figures do not include the time associated with flying the simulated flight, and if these numbers are included, the last duty day for Post-Duty crews approached sixteen hr and nine takeoffs and landings.

The results of the study revealed that, as expected, Post-Duty crews were significantly more "fatigued" than Pre-Duty crews. The former averaged less sleep and reported higher levels of fatigue than the latter. However, results on the crew performance measures indicated that this level of fatigue did not affect the performance of flightcrews in any operationally significant manner. As has been shown, the performance of Post-Duty crews was actually better than the performance of Pre-Duty crews on a number of dimensions relevant to flight safety. Post-Duty crews were rated as performing better by an expert observer on many significant dimensions, and although there were many measures that did not discriminate between the two groups, there were no cases where the performance of Pre-Duty crews was rated as superior. Post-Duty crews flew more stable approaches, and they tended to make fewer significant operational errors than did Pre-Duty crews.

To some, this very consistent pattern of results may seem paradoxical. However, it is important to note when considering how crews are usually assigned to flight duties, that there is a substantive difference between crews at the beginning of the duty cycle and crews at the end of a trip, regardless of the fatigue factor. After three days of flying with another crewmember, one knows a considerable amount about his or her operating characteristics, personality, and communication style. For example, copilots learn when and how an aircraft commander or captain likes to be assisted. Captains become familiar with the tendencies of their subordinates--how they supply information, and how best to elicit their input. Obviously, there is wide variation in human interaction, and the more individuals learn about their coworkers, the better they are able to tailor their behavior to the needs of a particular interaction.

In an effort to control for this familiarity factor, some crews were assigned to conditions differentially. In some cases, Post-Duty or tired crewmembers from *different* trips were assigned as a simulation crew, so they had not necessarily flown together recently. Likewise, Pre-Duty or rested crews were assigned to the simulation from the ranks of individuals who had just finished a trip together, but had been off-duty for three days. All of the data were then reanalyzed based on who had flown together on the most recent duty cycle or not (independent of the fatigue factor), and a very striking pattern of results emerged--the performance differences became stronger. It is readily apparent that crews in which the two pilots had flown together on the preceding duty cycle made significantly fewer errors than crews who had not, particularly the more serious types of errors--the Type II and Type III errors. This same pattern was evident for all of the other measures in these reanalyses, and they too exhibited larger performance differences. Recent operating experience appears to be a strong influence on crew performance and may have served as a countermeasure to the levels of fatigue present in Post-Duty crewmembers.

Examination of the flightcrew communication patterns in this study, as manifestations of the crew coordination process, suggests that this dimension is at least partially responsible for the performance differences. Crews that had flown together communicated significantly more overall, and these differences were in logical directions when compared with the significant performance variations. As in the Foushee and Manos (1981) study which found commands associated with better performance, captains in crews that had flown together issued more commands, but so did copilots (even though the frequency of copilot commands was relatively low). This finding may reflect a better understanding and division of responsibility between familiar crewmembers. There were more suggestions made in crews that had flown together, and more statements of intent by each crewmember, also indicating more willingness to exchange information.

Another replication of the Foushee and Manos findings revealed acknowledgements associated with better performance. There were many more acknowledgements of communications by both captains and first officers who had flown together. Foushee and Manos suggested that acknowledgements serve to reinforce the communications process, and the same phenomenon appears to have played a role in this study. It is particularly interesting that more disagreement was exhibited by first officers who had flown with the same captain during the preceding three days. This suggests that increased familiarity may be a partial cure for the frequently problematic hesitancy of subordinates to question the actions of captains.

There was significantly more non-task-related communication in crews that had not flown together, which may well indicate that they spent more time attempting to get to know each other. There was also significantly more tension release among crews who had not previously flown together. Also interesting was the presence of more frustration among captains who had not flown with the same copilot during the preceding duty cycle.

4.2. Operational Significance

It is the consistency of these results that is particularly striking. Duty-cycle exposure had no apparent effect on any of the parameters associated with flight safety. It is also interesting to note that the positive effects on crew coordination of some unknown amount of recent operating experience can be an effective countermeasure to the levels of fatigue associated with the duty cycles examined in this study. Whereas fatigue tends to be more prevalent during the later stages of a given duty cycle, crew coordination may be better as well because of the increased familiarity of crewmembers.

One of the obvious limitations of this study is that we are unable to closely examine the interaction of fatigue and crew familiarity. For example, it would be enlightening to look at the performance of tired crews who are familiar with each other versus those who are not and to repeat these comparisons for rested crews. Such an analysis could yield important insights into the effectiveness of crew familiarity as a countermeasure. Unfortunately, the sample only included one "fatigued" crews that had not flown together, while only two of the "rested" crews had flown together, and the restricted amount of data precluded these analyses.

Another limitation is related to the fact that we cannot determine from these data the amount or degree of familiarity necessary to produce a desired level of crew coordination. We can say with a fair amount of confidence that the recency of crew familiarity seems to be the key component, rather than the absolute amount. Most of the crews that had not flown together (as operationalized in these analyses) did know each other, and had flown together at some point in the past, but not within the last two or three months. Despite these rather compelling results, it would be a mistake to suggest a policy establishing the creation of relatively permanent crew assignments based on these data. There may be negative aspects associated with flying with the same person over a long period of time, such as complacency. boredom. and so on. It could well be that continued pairing of the same individuals would ultimately lead to a reversal of this pattern--worse performance associated with increased familiarity. Unfortunately, no research presently exists to substantiate this possibility (although the operational community generally believes this to be true), and it is not known how much familiarity might lead to this reversal.

It is interesting to speculate about the differences between this study and other research efforts that have demonstrated performance deficits associated with fatigue. It has been suggested (see Holding, 1983, for a review) that fatigue causes more minor types of errors because of its deleterious effect on the attentional process. This line of reasoning suggests that fatigue lowers attentional capacity, and the cumulative effect of lower attentional capacity coupled with low motivation on "less exciting" tasks tends to produce more error. It is arguable that since these non-engaging types of tasks tend to be of limited significance, any apparent performance deficits might be characterized minor, for the most part. However, this study provided no real support for this notion. There was a slightly larger number of Type I (minor) errors committed by Post-Duty crews, but the difference was not statistically reliable. Nevertheless, this remains a credible hypothesis considering the fact that traditional studies of fatigue effects have utilized performance measures that are not necessarily operationally significant.

The performance environment in this investigation was different from that found in traditional studies, and the high levels of realism and workload associated with segments of the simulation scenario no doubt produced average arousal levels greater than those typically found in lower fidelity studies measuring psychomotor effects. The high levels of crew workload associated with the operational problems faced by crews in this study demanded close attention, produced high motivation, and probably reduced boredom to a minimum. Since the subjects in this investigation were highly skilled, professional pilots performing identical tasks to those they perform in the real world, it is safe to assume that the motivation to perform well was quite high. This is in striking contrast to the boredom and lack of motivation often associated with classic, psychomotor measures such as reaction times. Thus it appears that arousal may be a key moderator of fatigue effects. Optimal levels of arousal appear to be harder to maintain when the operator is fatigued, but task demands may override this difficulty to some unknown extent. However, when task demands are low, the effects of fatigue may be manifested in performance deterioration more often. There is fairly convincing evidence that monitoring and vigilance during boring tasks is substantially degraded when the operator is fatigued (e.g., Holding, 1983).

If arousal does prove to be a key moderator of fatigue effects, it poses something of a complex puzzle for researchers interested in the implications of the fatigue-performance relationship for flight safety. On one hand, during low workload segments of flight, we might expect the effects of fatigue to be apparent, since low task demands produce low arousal. Thus, we can expect reduced performance when fatigue reaches some significant level, but since task demands are low (and the effects of performance decrements likely to be minor) it is reasonable to suggest that the effects of fatigue often may not be operationally significant. On the other hand, when task demands are high and if arousal does effectively counteract the effect of duty cycle exposure, then performance may not be affected (as in the present study). Periods of high task demand are precisely the times when good performance is most important, and performance parameters during these periods are usually the primary concern of aviation safety specialists. Again, one is drawn to the conclusion that fatigue may be present, but that its effects are not necessarily operationally significant. The problem with this line of reasoning is that occasionally minor attentional or performance lapses during periods of low task demand *can* precipitate a sequence of events leading to a serious incident or accident, as we have seen in the past. There was no evidence that fatigue produced such a sequence in this study, but the crew coordination process did appear to play a key role in eliminating the progression of a minor errors into major problems. As we have sought to demonstrate, coordination appeared to be better in short-haul crews at the end of the duty-cycle when they were presumably experiencing the highest cumulative effect of fatigue. These results clearly suggest that the system contains a "built-in" countermeasure, of sorts.

4.3. Implications for Long-Haul Operations

Despite the fact that these results are probably representative of the typical short-haul operation, it is not known whether the same phenomenon will be prevalent in long-haul, transmeridian operations or at higher levels of fatigue. While it is clear that the levels of fatigue associated with these short-haul duty cycles produced numerous psychological and physiological effects (see Gander et al., 1986), it is possible that these levels were not great enough to cause severe performance difficulties, as these results suggest. However, at some point, the level of fatigue or circadian dysrhythmia may well subsume the compensatory advantages of arousal or a well-coordinated crew operation. Long-haul flight operations, with longer duty days and other complications associated with time-zone shifts, may well produce more drastic effects. Another feature that distinguishes long- from short-haul operations is the predominance of extended stretches of low-workload cruise segments, in which arousal levels are no doubt lower, over longer periods of time, than in short-haul operations.

Moreover, too much crew familiarity, as in some long-haul operations where duty cycles can last 10 days or more, may lead to levels of complacency at which adverse effects on performance begin to manifest themselves. Such a phenomenon is particularly characteristic of groups in which too much cohesion or trust has developed, because of a reduced tendency to monitor or criticize the performance of others (Janis, 1972). There are presently no data with which to answer these questions. Plans are underway for further high-fidelity simulation work that may shed light on these issues.

REFERENCES

Bales, R. F.: Interaction process analysis: Theory, research, and application. Reading, Mass: Addison-Wesley, 1950.

Bartlett, F. C.: Fatigue following highly skilled work. Proceedings of the Royal Society 1943; Series B., 131:247-257. 247-257.

Brown, I. D.: Measurement of control skills, vigilance, and performance of a subsidiary task during 12 hrs. of car driving. Ergonomics 1967; 10:665-673. 665-673.

Chiles, W. D.: Experimental studies of prolonged wakefulness. W.D.A.C. Tech. Report No. 55-395 1955, Dayton, Ohio.

Cooper, G. E.; White, M. D.; and Lauber, J. K. (Eds.): Resource management on the flight deck. NASA CP-2120, 1979.

Dureman, E. I.; and Boden, C.: Fatigue in simulated car driving. Ergonomics 1972. 15:299-308.

Foushee, H. C.: Dyads and triads at 35,000 feet: Factors affecting group process and aircrew performance. American Psychologist 1984. 39:885-893.

Foushee, H. C.; and Helmreich, R. L.: Group interaction and flightcrew performance. In E. L. Wiener and D. C. Nagel (Eds.). Human factors in modern aviation. New York: Academic Press, 1986, in press.

Foushee, H. C.; and Manos, K. L.: Information transfer within the cockpit: Problems in intracockpit communications. In C. E. Billings and E. S. Cheaney (Eds.) Information transfer problems in the aviation system. NASA TP-1875, 1981.

Gagne, R. M.: Task variables in fatigue. In W. F. Floyd and A. T. Welford (Eds.). Symposium on fatigue. London: H. K. Lewis, 1953.

Gander, P. H.; Graeber, R. C.; Foushee, H. C.; and Lauber, J. K.: Crew factors in flight operations II: Psychophysiological responses to short-haul air transport operations. NASA TM-88321, 1986.

Graeber, R. C.: Alterations in performance following rapid transmeridian flight. In F. M. Brown and R. C. Graeber (Eds.). Rhythmic aspects of behavior. Hillsdale, NJ: Laurence Erlbaum, 1982.

Graeber, R. C.; Foushee, H. C.; and Lauber, J. K.: Dimensions of flight crew performance decrements: Methodological implications for field research. In H. M. Wegman (Ed.). Breakdown in human adaptation to stress: Towards a multidisciplinary approach. The Hague: Nijhoff, 1984.

Hart, S. G.; Battiste, V.; and Lester, P. T.: Popcorn: A supervisory control simulation for workload and performance research. Proceedings of the 20 Annual Conference on Manual Control 1984.

Holding, D. H.: Fatigue. In G. R. J. Hockey (Ed.). Stress and fatigue in human performance. New York: John Wiley and Sons, 1983.

Janis, I. L.: Victims of groupthink: A psychological study of foreign policy decisions and fiascos. Boston: Houghton-Mifflin, 1972.

Kazdin, A. E.: Single case research designs. New York: Oxford University Press, 1982.

Klein, K. E.; Bruner, H.; Holtmann, H.; Rehme, H.; Stolze, J.; Steinhoff, W. D.; and Wegman, H. M.: Circadian rhythm of pilots' efficiency and effects of multiple time zone travel. Aerospace Medicine 1970; 41:126-132.

Klein, K. E.; and Wegman, H. M.: Significance of circadian rhythms in aerospace operations. AGARDOGRAPH No. 247. Neurilly-Sur-Seine, France, 1980.

Lauber, J. K.; and Foushee, H. C.: Guidelines for line-oriented flight training, (Vol. 1). NASA CP-2184, 1981.

McFarland, R. A.: Human factors in air transportation. New York: McGraw-Hill, 1953.

Moses, J. M.; Lubin, L.; Naitoh, P.; and Johnson; L. C.: Evaluation of the effects of sleep loss: The NPRU mood scale. Technical Report 74-25, 1974.

Ruffell Smith, H. P.: A simulator study of the interaction of pilot workload with errors, vigilance, and decisions. NASA TM-78482, 1979.

Wever, R. A.: The circadian system of man: Results of experiments under temporal isolation. New York: Springer-Verlag, 1979.

APPENDIX A

SHORT-HAUL SIMULATOR STUDY OBSERVER RATING FORM (v.5)

Condition____________________ Pilot Flying____________________(Capt/FO)

Capt. ID____________ F/O ID____________ Observer____________________

Use the following ratings for all categories:

1 - below average
2 - slightly below average
3 - average
4 - slightly above average
5 - above average
n/a - not observed or not applicable

PREFLIGHT

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

TAXI/TAKEOFF

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness (mach trim)	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness (T/O alt.)	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

CLIMB

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness (T-storm)	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

CRUISE

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

APPROACH & MISSED APPROACH

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Stress Management (missed appr.)	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

EMERGENCY PROCEDURE--SYSTEM A HYDRAULIC FAILURE

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Stress Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

CRUISE TO ALTERNATE

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Stress Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

APPROACH & LANDING

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Stress Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

GENERAL COMMENTS (briefly summarize your impressions of this crew)

ERRORS (list in detail all errors committed by the crew during this session)

APPENDIX B

CHECK PILOT OBSERVER OVERALL RATING FORM (Captain form*)

Condition ________________ Pilot Flying ______________________

Capt. ID________ FO ID_______ Rater ____________

Use the following ratings: 1 = below average
2 = slightly below average
3 = average
4 = slightly above average
5 = above average

For each item, circle the rating that best describes the captain.

1. Overall knowledge of aircraft and procedures.

   1 2 3 4 5

2. Overall technical proficiency.

   1 2 3 4 5

3. Overall smoothness (flying pilot only)

   1 2 3 4 5

4. Crew coordination and internal communication (intentions are clear to all crew members, proper callouts made, etc.).

   1 2 3 4 5

5. External communication (ATC instructions verified, properly monitored, etc.)

   1 2 3 4 5

6. Overall motivation

   1 2 3 4 5

7. Command ability

   1 2 3 4 5

8. Vigilance

1 2 3 4 5

9. Overall performance

1 2 3 4 5

* First Officer form was identical except that Item #7 was omitted.

APPENDIX C

PILOT WORKLOAD RATING FORM

Pilot Name__________________________ Date ____________

Position_____________ PF______ PNF______ (check one) ----------
----

1. Please circle the number which best corresponds to the overall level of workload.

0	1	2	3	4	5	6
low						high

2. Please rate your own performance on the simulated flight.

0	1	2	3	4	5	6
very poor						very good

3. How much attention did this flight demand?

0	1	2	3	4	5	6
very little						a great deal

4. How complex was the flight?

0	1	2	3	4	5	6
not at all						very

5. How much time pressure did you feel during the flight?

0	1	2	3	4	5	6
none						a great deal

6. How much mental effort did the flight require?

0	1	2	3	4	5	6
none						a great deal

7. How busy were you?

0	1	2	3	4	5	6
not at all						very

8. How <u>difficult</u> was the flight?

0	1	2	3	4	5	6
easy						difficult

9. How <u>motivated</u> were you to perform?

0	1	2	3	4	5	6
not at all						very

10. How do you <u>feel</u> after the simulated flight?

0	1	2	3	4	5	6
fresh						tired

0	1	2	3	4	5	6
relaxed						tense

APPENDIX D

PHYSICAL STATE DATA FORM

ID# ______ Condition __________ Capt. or FO (circle one)

Please fill in the approximate times you went to sleep and when you awoke for the previous four nights as best you can remember.

EST or EDT (circle one)

	Time Asleep	Time Awoke	Total Nap Time	Total Sleep Time
Last night	__________	__________	__________(hrs/min)	__________(hrs)
2 nights ago	__________	__________	__________(hrs/min)	__________(hrs)
3 nights ago	__________	__________	__________(hrs/min)	__________(hrs)
4 nights ago	__________	__________	__________(hrs/min)	__________(hrs)

Rate your last night's sleep from least (1) to most (5)

Difficulty falling asleep? 1 2 3 4 5 Difficulty arising? 1 2 3 4 5
How deep was your sleep? 1 2 3 4 5 How rested you feel? 1 2 3 4 5

Please answer the following items about how you feel right now.

	not at all	a little	moder-ately	quite a bit	ex-tremely
active	0	1	2	3	4
vigilant	0	1	2	3	4
annoyed	0	1	2	3	4
carefree	0	1	2	3	4
cheerful	0	1	2	3	4
considerate	0	1	2	3	4
defiant	0	1	2	3	4
dependable	0	1	2	3	4
sleepy	0	1	2	3	4
dull	0	1	2	3	4
efficient	0	1	2	3	4
friendly	0	1	2	3	4

full of pep	0	1	2	3	4
grouchy	0	1	2	3	4
happy	0	1	2	3	4
jittery	0	1	2	3	4
kind	0	1	2	3	4
lively	0	1	2	3	4
pleasant	0	1	2	3	4
relaxed	0	1	2	3	4
forgetful	0	1	2	3	4
sluggish	0	1	2	3	4
tense	0	1	2	3	4
clear thinking	0	1	2	3	4
tired	0	1	2	3	4
hard working	0	1	2	3	4

Place a mark on the line at the point which best corresponds to your present state of alertness.

MOST ALERT MOST DROWSY

APPENDIX E

COMMUNICATION CATEGORIES

1) COMMAND: a specific assignment of responsibility by one group member to another.

2) OBSERVATION: recognizing and/or noting a fact or occurrence relating to the task.

3) SUGGESTION: recommendation for a specific course of action.

4) STATEMENT OF INTENT: announcement of an intended action by speaker. Includes statements referring to present and future actions, but not to previous actions.

5) INQUIRY: a request for factual information relating to the task. Not a request for action.

6) AGREEMENT: a response in concurrence with a previous speech act; a positive evaluation of a prior speech act.

7) DISAGREEMENT: a response NOT in concurrence with a previous speech act; a negative evaluation of a prior speech act.

8) ACKNOWLEDGEMENT: a) makes known that a prior speech act was heard; b) does not supply additional information; c) does not evaluate a previous speech act.

9) ANSWER SUPPLYING INFORMATION: speech act supplying information beyond mere agreement, disagreement, or acknowledgment.

10) RESPONSE UNCERTAINTY: statement indicating uncertainty or lack of information with which to respond to a speech act.

11) TENSION RELEASE: laughter or humorous remark.

12) FRUSTRATION/ANGER/DERISIVE COMMENT: statement of displeasure with self, other persons, or some aspect of the task; or a ridiculing remark.

13) EMBARRASSMENT: any comment apologizing for an incorrect response, etc.

14) REPEAT: restatement of a previous speech act without prompting.

15) CHECKLIST: prompts and replies to items on a checklist.

16) NON-TASK RELATED: any speech act referring to something other than the present task.

17) NON-CODABLE: speech act which in unintelligible or unclassifiable with respect to the present coding scheme.

18) ATC COMMUNICATION: any communication over the radio with ATC, dispatch, "the company", etc.

APPENDIX F

SAMPLE AIRCRAFT PERFORMANCE DATA

DATE AND TIME:	17-JUL-1984 20:44:23		
AIRSPEED:	277.03580	ALTITUDE:	19023.11
MAG. HEADING:	53.70029	VERT. SPEED:	979.9
ENG. #1 EPR:	1.812	VOR/LOC DEV:	0.135
G/S DEV	8.0000000	FLAP DEGREES:	0.000
GEAR POS.:	0.00000	TIME SEC.:	68899.70
#1 NAV FREQ.:	110400	#1 DME:	117

DATE AND TIME:	17-JUL-1984 20:44:38		
AIRSPEED:	280.26279	ALTITUDE:	19028.15
MAG. HEADING:	48.10065	VERT. SPEED:	-522.4
ENG. #1 EPR:	1.553	VOR/LOC DEV:	0.141
G/S DEV	8.0000000	FLAP DEGREES:	0.000
GEAR POS.:	0.00000	TIME SEC.:	68914.70
#1 NAV FREQ.:	110400	#1 DME:	102

DATE AND TIME:	17-JUL-1984 20:44:53		
AIRSPEED:	280.84479	ALTITUDE:	18998.43
MAG. HEADING:	51.12605	VERT. SPEED:	81.9
ENG. #1 EPR:	1.555	VOR/LOC DEV:	0.052
G/S DEV	8.0000000	FLAP DEGREES:	0.000
GEAR POS.:	0.00000	TIME SEC.:	68929.70
#1 NAV FREQ.:	110400	#1 DME:	85

DATE AND TIME:	17-JUL-1984 20:45:08		
AIRSPEED:	282.92468	ALTITUDE:	18985.18
MAG. HEADING:	51.75150	VERT. SPEED:	-127.4
ENG. #1 EPR:	1.554	VOR/LOC DEV:	0.053
G/S DEV	8.0000000	FLAP DEGREES:	0.000
GEAR POS.:	0.00000	TIME SEC.:	68944.70
#1 NAV FREQ.:	110400	#1 DME:	69

DATE AND TIME:	17-JUL-1984 20:45:23		
AIRSPEED:	280.86337	ALTITUDE:	19002.85
MAG. HEADING:	51.90620	VERT. SPEED:	107.9
ENG. #1 EPR:	1.554	VOR/LOC DEV:	0.077
G/S DEV	8.0000000	FLAP DEGREES:	0.000
GEAR POS.:	0.00000	TIME SEC.:	68959.70
#1 NAV FREQ.:	110400	#1 DME:	53

DATE AND TIME:	17-JUL-1984 20:45:38		
AIRSPEED:	285.85156	ALTITUDE:	18993.17
MAG. HEADING:	51.97639	VERT. SPEED:	-6.0
ENG. #1 EPR:	1.529	VOR/LOC DEV:	0.113
G/S DEV	8.0000000	FLAP DEGREES:	0.000
GEAR POS.:	0.00000	TIME SEC.:	68974.70
#1 NAV FREQ.:	110400	#1 DME:	37

DATE AND TIME:	17-JUL-1984 20:45:53		
AIRSPEED:	286.68530	ALTITUDE:	18996.42
MAG. HEADING:	51.92190	VERT. SPEED:	4.8
ENG. #1 EPR:	1.530	VOR/LOC DEV:	0.020
G/S DEV	8.0000000	FLAP DEGREES:	0.000
GEAR POS.:	0.00000	TIME SEC.:	68989.70
#1 NAV FREQ.:	114100	#1 DME:	971

1. Report No. NASA TM 88322	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle CREW FACTORS IN FLIGHT OPERATIONS: III. THE OPERATIONAL SIGNIFICANCE OF EXPOSURE TO SHORT-HAUL AIR TRANSPORT OPERATIONS		5. Report Date August 1986
		6. Performing Organization Code
7. Author(s) H. Clayton Foushee, John K. Lauber, Michael M. Baetge (Informations General Corporation, Palo Alto, CA) and Dorothea B. Acomb (San Jose State University, San Jose, CA 95192)		8. Performing Organization Report No. A-86338
9. Performing Organization Name and Address Ames Research Center Moffett Field, CA 94035		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code 505-67-41

15. Supplementary Notes

Point of Contact: H. Clayton Foushee, Ames Research Center, MS 239-21, Moffett Field, CA 94035
(415) 694-6114 or FTS 464-6114

16. Abstract

Excessive flightcrew fatigue as a result of trip exposure has long been cited as a factor with potentially serious safety consequences. Laboratory studies have implicated fatigue as a causal factor associated with varying levels of performance deterioration depending on the amount of fatigue and the type of measure utilized in assessing performance. From an operational standpoint, these studies have been of limited utility because of the difficulty of generalizing laboratory task performance to the demands associated with the operation of a complex aircraft.

This study examined the performance of 20 volunteer twin-jet transport crews in a full-mission simulator scenario that included most aspects of an actual line operation. The scenario included both routine flight operations and an unexpected mechanical abnormality which resulted in a high level of crew workload. Half of the crews flew the simulation within two to three hours after completing a three-day, high-density, short-haul duty cycle (Post-Duty condition). The other half of the crews flew the scenario after a minimum of three days off duty (Pre-Duty condition).

The results of this study revealed that, not surprisingly, Post-Duty crews were significantly more fatigued than Pre-Duty crews. However, a somewhat counter-intuitive pattern of results emerged on the crew performance measures. In general, the performance of Post-Duty crews was significantly better than the performance of Pre-Duty crews. Post-Duty crews were rated as performing better by an expert observer on a number of dimensions relevant to flight safety. Analyses of the flightcrew communication patterns revealed that Post-Duty crews communicated significantly more overall, suggesting, as has previous research, that communication is a good predictor of overall crew performance.

Further analyses suggested that the primary cause of this pattern of results is the fact that crewmembers usually have more operating experience together at the end of a trip, and that this recent operating experience serves to facilitate crew coordination, which can be an effective countermeasure to the fatigue present at or near the end of a duty cycle. These results have important aircrew training and aviation safety implications.

17. Key Words (Suggested by Author(s)) Communications Resource management Fatigue		18. Distribution Statement Unlimited Subject category - 51	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 63	22. Price* A04

*For sale by the National Technical Information Service, Springfield, Virginia 22161